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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> :	A1	(11) International Publication Number:	WO 00/36055
C10L 1/02, 1/14		(43) International Publication Date:	22 June 2000 (22.06.00)

(21) International Application Number:	PCT/GB99/04155	(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date:	15 December 1999 (15.12.99)	
(30) Priority Data:	9827592.8 15 December 1998 (15.12.98) GB	
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(54) Title: FUEL COMPOSITION

(57) Abstract

There is described a method of reducing the vapour pressure (RVP) of a gasoline/alcohol mixture which comprises adding a surfactant composition comprising an alkanolamide, an alkoxylated alcohol and an alkoxylated fatty acid to a gasoline/alcohol mixture.

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## FUEL COMPOSITION

The invention relates to a novel method of reducing the vapour pressure of fuels and to the new use of compositions.

5

It is well known that liquid fuels when burned in an internal combustion engine can give rise to pollution and other undesired side effects. Furthermore, the relatively high vapour pressure of most liquid hydrocarbon fuels is known to give rise to environmental and safety problems upon storage and transportation. Numerous 10 proposals have been advanced to reduce these side effects and enhance efficiency, eg miles per gallon. It has been realised that surfactants can play a useful role in this context but so far as we are aware none has satisfied the modern commercial criteria. It is one object of this invention to meet the need.

15 According to the US Environmental Protection Agency (EPA), volatile organic compound (VOC) emissions from gasoline are, as ozone precursors, a major contributor to the nation's serious ground level ozone problem, which harms human health and the public welfare. In addition to automotive emissions, gasoline evaporation occurs during refining, during commercial handling, transportation, and 20 storage, and during refuelling. Because gasoline evaporation is a significant environmental problem, work was initiated at the National Alternative Fuels Laboratory (NAFL) of the University of North Dakota Energy & Environmental Research Center (EERC) to investigate evaporation rates of various gasolines and gasoline-oxygenate blends and the composition of their evaporative emissions. One 25 aspect of the work, which was funded by the US Department of Agriculture (USDA), was to compare evaporation rates and compositions of E10 evaporative emissions with those of nonethanol-blended base fuels.

30 Widespread commercial use of E10 fuels was originally promoted as a means to reduce gasoline consumption during the oil embargo of 1973. Current interest in ethanol as a transportation fuel involves its use as an oxygenate to reduce carbon

monoxide (CO) combustion emissions. Also, its octane-boosting quality makes it useful as a replacement for octane-supplying aromatics that are slated for removal from reformulated gasolines to be sold in ozone non-attainment areas. Despite its desirable qualities as a fuel and the fact that it is renewable, ethanol has serious 5 competition. Ethanol supporters are locked in a long-term debate with supporters of the other major commercially available gasoline oxygenate, methyl *tertiary*-butyl ether (MTBE), over which oxygenate is best for the environment.

A major point of contention in the debate is the approximate one-pound per square 10 inch (psi) increase in RVP that occurs upon addition of ethanol to base fuel at a concentration of 10 vol%. However, while RVP is a useful indicator of a fuel's volatility, it is less useful as an indicator of how atmospheric interaction of vapour from the fuel (generated via evaporation or displacement during tank filling) may affect the environment in terms of ground level ozone production. Because gasolines 15 are complex mixtures of over 200 components, the overall ozone-producing potential of a particular gasoline's vapour will depend not only on how much vapour is emitted, but also on the ozone-producing potential and concentration of each vapour component.

20 Surfactants have long had utility as additives which can affect the performance of fuels such as gasoline and diesel. British Patent No 2217229 describes a solubilising compound as a fuel additive. In particular there is described a composition comprising;

25 48 parts by volume of an alcohol ethoxylate;  
3-8 parts by volume of lauric diethanolamide;  
3-8 parts by volume of oleic diethanolamide; and  
1.5-4 parts by volume of a polyglycol ether such as ethoxylated oleic acid.

30 Such compositions are useful as fuel additives and enable the solubilisation of water in fuels thus reducing its potential corrosive effect. However, the compositions are disadvantageous in that, *inter alia*, they require a high additive to fuel ratio.

Furthermore, they do not address the problems of emissions of gases such as CO, CO<sub>2</sub> and NO<sub>X</sub>, nor do they address the problems of evaporative loss due to the high vapour pressure of the fuel composition.

5 International Patent Application No WO 98/17745 describes an alternative formulation which comprises,

25% w/w of a diethanolamide,  
50% w/w of an ethoxylated alcohol, and  
10 25% w/w of a fourteen carbon chain fatty acid with seven ethoxylate groups.

WO '745 especially describes fuel compositions comprising, *inter alia*, an additive made up of a fatty acid diethanolamide, an alcohol ethoxylate and an ethoxylate of a fatty acid, the degree of ethoxylation being selected so that a long term stable fuel 15 composition is formed and, in particular, wherein, by carefully selecting the degree of ethoxylation, a balanced blend can be produced, such that the molecular weight ratios of each of the three components are substantially equivalent, for example, the molecular weight ratios are 1:1:1.

20 Whilst such additives provide significant reductions in emissions and are useable at low concentrations, there is still a need for a fuel composition which is capable of reducing emissions whilst maintaining performance levels.

It is known that to meet some legislation requirements fuels must have a low Reid  
25 Vapour Pressure value (RVP), e.g. under California State law, the RVP must be below 7psi.

Some modern day gasoline contains a small percentage of a condensate from natural  
gas pipelines. Gasoline is made up from a range of hydrocarbons, which is  
30 determined by the refining and blending processes. They may also contain minor amounts of comparatively volatile contaminants picked up during transportation, for

example, through pipe lines which have been previously used for transportation of natural gases. Pentanes are a range of C5 hydrocarbons that are typically left in the crude oil cut after the gas condensates are removed. Natural gas (methane) is extracted first from the oil field, ethane is increasingly also extracted at the well for 5 petrochemical production of ethylene, while LPG, a mixture of C3 and C4 hydrocarbons, is liquefied under moderate pressure for use as a gas fuel. Pentane is usually the first cut off the Crude Distillation Unit at the refinery and the disposal of pentane creates a problem for the petroleum industry. Pentane has little value as a petrochemical feedstock, and blending it into the gasoline pool has the undesirable 10 effect of raising the RVP. The aforementioned contaminants, as well as low boiling fractions arising from the refining and blending processes, all have the undesirable effect of increasing the vapour pressure of the gasoline. This undesirable effect will be further exacerbated if the fuel is blended with certain volatile oxygenating agents such as ethanol. Thus the condensate is a light fraction which is primarily pentanes 15 although other hydrocarbons may be present. The condensate adversely affects the RVP, especially when the gasoline contains an alcohol such as ethanol.

It is known that when gasoline and an alcohol are mixed, the resultant mixture has an increased vapour pressure. We have now surprisingly found that by adding certain 20 surfactant compositions to a gasoline and alcohol mixture a reduction in vapour pressure (RVP) can be achieved.

Thus, according to the invention we provide a method of reducing the vapour pressure of a gasoline/alcohol mixture which comprises adding a surfactant 25 composition comprising an alkanolamide, an alkoxylated alcohol and an alkoxylated fatty acid to a gasoline/alcohol mixture.

By the term vapour pressure we mean the Reid Vapour Pressure (RVP). Thus the method of the invention preferably reduces the RVP of the gasoline mixture to less 30 than 8psi, preferably less than 7psi and especially between 6 and 7psi.

For the purposes of this invention the RVP is measured using the test method of ASTM D5191. Thus the vapour pressure is given as psi at 37.8°C.

It is a novel aspect of the invention to use the aforementioned surfactant composition  
5 in the reduction of RVP.

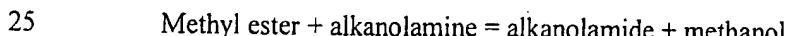
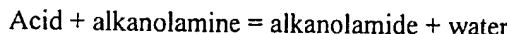
According to a further aspect of the invention we provide the use of an additive composition as hereinbefore described in the manufacture of a fuel composition having an RVP of less than 8psi.

10

The alkanolamide is preferably an ethanolamide and more preferably a diethanolamide. Especially preferred are the diethanolamides and particularly the super diethanolamides. By the term super diethanolamide we mean a diethanolamide in which the nitrogen is substituted by an acyl substituent e.g. acyl C<sub>5</sub> to C<sub>20</sub>,  
15 preferably C<sub>8</sub> to C<sub>16</sub>, more preferably C<sub>10</sub> to C<sub>15</sub>. The most preferred diethanolamide has a C<sub>12</sub> acyl substituent i.e. lauryl diethanolamide. Where the amides are derived from natural products this moiety will have an even number of carbon atoms, e.g. 12 for the lauryl derivative. Note, the alkyl part of this group is the R group which will be an odd number.

20

There are three commercial routes to alkanolamides;



These are listed in order of increasing product quality. The route via the acid often uses an excess of alkanolamine to produce a product higher in amide than is obtainable from the acid if a stoichiometric ratio is used; these products are  
30 sometimes referred to as super amides.

The alkoxylated alcohol is preferably an ethoxylated alcohol. It is essential that the ethoxylated alcohol is an oil soluble alcohol. Therefore, alkanols are preferred and these may be primary, secondary or tertiary alkanols and especially primary alkanols.

5 As the oil solubility of the alcohol may vary with the carbon chain length of the ethoxylated alkanol, the alkanol is preferably a C<sub>5</sub> to C<sub>22</sub> alkanol, more preferably C<sub>5</sub> to C<sub>15</sub> alkanol. The ethoxylated alcohol may comprise a mixture of alkanols. However, it is preferred that in such mixtures one alkanol will predominate. Thus,

10 the most preferred alkanol is predominantly a C<sub>9</sub> to C<sub>11</sub> alkanol. In addition the degree of ethoxylation of the alcohol may be varied and the oil solubility will, generally, decrease with the increase in the degree of ethoxylation. It is preferred that the ethoxylate to alcohol ratio is greater than 2. More preferably, the ethoxylate to alcohol ratio is from between 1 and 10, preferably between 1 and 5, more preferably between 1 and 3 and especially between 2 and 3. A commercially available ethoxylated alcohol is especially preferred in which the ethoxylate to alcohol ratio is

15 2.75. Such an alcohol ethoxylate is available as NEODOL 91/2.5.

The fatty acid ethoxylate may comprise any conventionally known fatty acid ethoxylate. Thus the fatty acid ethoxylate may be derived from a fatty acid having from 8 to 20 carbon atoms, preferably from 10 to 18 and most preferably 14 carbon atoms (myristic acid).

The degree of ethoxylation is chosen to optimise performance in the blend with the other two selected surfactants and may be from 1 to 20, but more preferably from 5 to 12. A suitable product within this range would be, for example that derived from the

25 addition of 7 molecules of ethylene oxide to 1 mole of myristic acid.

The values will depend on the length of the hydrophilic chain, typically an ethoxylate chain. The length of the chain will increase the extent of solubilisation because of a greater ability to solubilise.

As with the compositions described in WO98/17745, a blend of surfactants is preferred, preferably by selecting one appropriate to the fuel, say 10 to 18 for hydrocarbon fuel, most preferably 13. In the case of an alcohol the HLB value of the surfactant is between 3 and 7, most preferably about 4. But the addition of 5 surfactants normally create ratios of 1:1 or high volume emulsions or 5:1 ratios when the solubalisation is required at 1:100.

The invention has the ability to unify the HLB requirements of any liquid fuel which in turn allows for one dose to be used in any fuel from C5 carbon chains up. The 10 benefit being the amount of treatment directly related to the co-solvency ability.

Preferably the ethoxylate of the fatty acid makes up about 25% by volume of the additive and further preferably the alcohol ethoxylate comprises 50% by volume of the additive.

15

The surfactant additive may be added to a hydrocarbon fuel, eg diesel, petrol or alcohol, such as ethanol which may or may not be contaminated with water.

The fuel composition comprising a fuel and a fuel additive wherein the additive to 20 fuel ratio is 0.5 – 1:1200.

The alcohol to hydrocarbon fuel ratio is from 1:8 to 1:9. Water may be present, e.g. as condensate, or added separately, in water: alcohol: fuel ratio of 0:1:8 to 0.5:1:9 and preferably from 0.25:1:8 to 0.25:1:9.

25

The additive may be present in an additive to fuel/alcohol ratio of about 0.5 – 1:1000. Preferably the additive to fuel ratio is about 1:1000, most preferably about 1:1200. In this context the fuel is the hydrocarbon fuel and alcohol mixture.

**Example 1**

Different blends shown in Table 1 were made and subjected to gas chromatography. The ratio of hydrocarbon: ethanol was measured by gas chromatography. The results 5 were used to indicate the extent to which the content of the ethanol could be incorporated without exceeding an increase in the temperature at which the volatile ingredients evaporated. The results showed the amount of ethanol that could be incorporated into the hydrocarbon without increasing the temperature at which the volatile components evaporated.

10

The additive comprised 60% by weight ethanolethoxylate, 20% by weight diethanolamide and 20% by weight of lauric diethanolamide. Our investigation suggests that these interact to form a blend in which the ethanolamide is a backbone.

15 **Example 2**

Different blends were made up and the RVP determined. The following results were obtained:

**Table II**

Sample	Gasoline	Ethanol	Additive as above	Water	RVP (1)	RVP (2)	RVP (3)
1	90	10	-	-	7.48	7.7	7.58
2	87.5	10	2.5	-	7.18	7.41	7.29
3	85.0	10	2.5	2.5	6.87	7.11	6.98
4	85.0	10	2.5	2.5	6.96	7.19	7.06

20

The RVP value was measured according to ASTM D5191 and is the mean value of results calculated according to CARB (1), EPA (2) and ASTM (3) methods. In Samples 2, 3 and 4 the gasoline included a proportion of a condensate which was mainly pentanes. These results demonstrate a tendency of the additive to reduce the

RVP value, and that by selecting appropriate proportions a fuel composition can be made to meet the requirements of local legislation.

**Table 1**

Sample	Hydrocarbon (a)	Ethanol (b)	Pentane	Additive	Ratio (a):(b)
1	90	10	0	0	15:1
2	89	10	0	1	16.7:1
3	82	13.5	4.5	0	17.75:1
4	77.5	13.5	4.5	4.5	11.69:1

5

**Example 3**

Various tests were conducted according to ASTM D-5191. The results are given in  
10 Tables III to IX.

**Example 4**

15 Various tests were conducted according to the 1975 US Federal City Gasoline Test.  
The results are given in Tables X to XIII;

Table X: Tests on CARB Gasoline

Table XI: Tests on EPA

20 Table XII: Tests on Gasohol

25

**CLAIMS**

1. A method of reducing the vapour pressure of a gasoline/alcohol mixture which comprises adding surfactant composition comprising an alkanolamide, an alkoxylated alcohol and an alkoxylated fatty acid to a gasoline/alcohol mixture.  
5
2. A method according to Claim 1 characterised in that the RVP is less than 7psi.
- 10 3. A method according to Claim 2 characterised in that the RVP is less than 7psi.
4. A surfactant composition according to Claim 3 characterised in that the RVP is between 6 and 7psi.  
15
5. A method according to Claim 1 characterised in that the alkanolamide is a diethanolamide.
6. A method according to Claim 5 characterised in that the nitrogen in the diethanolamide is substituted by an alkyl C<sub>5</sub> to C<sub>20</sub> substituent.  
20
7. A surfactant composition according to Claim 6 characterised in that the diethanolamide is a lauryl diethanolamide.
- 25 8. A method according to Claim 1 characterised in that the alkoxylated alcohol is an ethoxylated alcohol.
9. A method according to Claim 8 characterised in that the ethoxylated alcohol is a C<sub>5</sub> to C<sub>15</sub> alkanol.  
30

10. A method according to Claim 8 characterised in that the ethoxylated alcohol comprises a mixture of alkanols in which one alkanol predominates.
11. A method according to Claim 8 characterised in that the predominate alkanol  
5 is a C<sub>9</sub> to C<sub>11</sub> alkanol.
12. A method according to Claim 8 characterised in that the ethoxylate to alcohol ratio is from between 1 and 5.
- 10 13. A method according to Claim 8 characterised in that the ethoxylated alcohol is NEODOL 91/2.5.
14. A method according to Claim 1 characterised in that the fatty acid group is a C<sub>8</sub> to C<sub>20</sub> fatty acid.  
15
15. A method according to Claim 14 characterised in that the fatty acid group is a C<sub>14</sub> fatty acid (myristic acid).
16. A method according to Claim 1 characterised in that the ester moiety of the  
20 fatty acid ester is an alkyl ester.
17. A method according to Claim 16 characterised in that the alkyl group is a C<sub>1</sub> to C<sub>10</sub> alkyl.
- 25 18. A method according to Claim 1 characterised in that the composition comprises 25% v/v of the fatty acid ester.
19. A method according to Claim 1 characterised in that the composition  
comprises 50% v/v of the alcohol ethoxylate.  
30

20. A method according to claim 1 characterised in that the surfactant additive to fuel/alcohol ratio is from 0.5:1200 to 1:1000.

21. The use of a surfactant composition comprising an alkanolamide, an 5 alkoxylated alcohol and an alkoxylated fatty acid ester in the manufacture of a fuel composition having an RVP of less than 8psi.

22. A method of manufacturing a mixture comprising gasoline, alcohol and a surfactant composition, said surfactant composition comprising an alkanolamide, an 10 ethoxylated alcohol and an alkoxylated fatty acid characterised in that the method comprises blending the alcohol and surfactant followed by blending with gasoline.

23. A method substantially as described with reference to the accompanying examples.

15

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TABLE III

LABORATORY TESTS RESULTS 05/28/99		ATTN: Attn	
CLIENT I.D.....	C - BASE CARBOB (GASOLINE)	LABORATORY I.D. ....	990554-0034
DATE SAMPLED.....	05/26/99	DATE RECEIVED.....	05/26/99
TIME SAMPLED.....	12:02	TIME RECEIVED.....	12:02
WORK DESCRIPTION.....	C	REMARKS.....	
TEST DESCRIPTION	FINAL RESULT	LIMIT'S/DILUTION	UNITS OF MEASURE
REID EQUIVALENT VAPOUR PRESSURE	*1	0.10	PSI
RVP CARB CALCULATION	5.82*	0.10	PSI
RVP EPA CALCULATION	6.08	0.10	PSI
RVP ASTM CALCULATION	5.94	0.10	PSI
PRESSURE TOTAL/GRABNER INSTRUMENT	6.73	0.10	PSI

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TABLE IV

JOB NUMBER: 990554		LABORATORY TESTS RESULTS 05/28/99		ATTN: Attn	
CLIENT I.D.....	CARBOB 90/10	BASE + 10% ETOH		LABORATORY I.D.....	990554-0039
DATE SAMPLED.....	05/20/99			DATE RECEIVED.....	05/20/99
TIME SAMPLED.....	16:01			TIME RECEIVED.....	16:01
WORK DESCRIPTION....	CARBOB 90/10			REMARKS.....	1-500ml amber btl
TEST DESCRIPTION	FINAL RESULT	LIMITS/ TOLERANCE	UNITS OF MEASURE	TEST METHOD	DATE
REID EQUIVALENT VAPOUR PRESSURE	*1		PSI	ASTM D-5191	05/28/99
RVP CARB CALCULATION	7.16*	0.10	PSI	ASTM D-5191 (CARB)	
RVP EPA CALCULATION	7.41	0.10	PSI	ASTM D-5191 (EPA)	
RVP ASTM CALCULATION	7.29	0.10	PSI	ASTM D-5191 (ASTM)	
PRESSURE TOTAL/GRABNER INSTRUMENT	8.12	0.10	PSI	ASTM D-5191	

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TABLE V

JOB NUMBER: 990554		LABORATORY TESTS RESULTS 05/28/99		ATTN: Attn	
CLIENT I.D.....:	CARBOB 90/10 LN	BASE + 10% ETOH		LABORATORY I.D.....:	990554-0040
DATE SAMPLED.....:	05/20/99	+ 1% 25% NEODOL		DATE RECEIVED.....:	05/20/99
TIME SAMPLED.....:	16:01	37.5% OPE		TIME RECEIVED.....:	16:01
WORK DESCRIPTION....:	CARBOB 90/10 LN	37.5% ATLAS		REMARKS.....:	1-500ml amber btl
TEST DESCRIPTION	FINAL RESULT	LIMITS/DILUTION	UNITS OF MEASURE	TEST ME HOD	DATE
REID EQUIVALENT VAPOUR PRESSURE	*1			ASTM D-5191	05/28/99
RVP CARB CALCULATION	6.79	0.10	PSI	ASTM D-5191 (CARB)	
RVP EPA CALCULATION	7.04	0.10	PSI	ASTM D-5191 (EPA)	
RVP ASTM CALCULATION	6.91	0.10	PSI	ASTM D-5191 (ASTM)	
PRESSURE TOTAL/GRABNER INSTRUMENT	7.73	0.10	PSI	ASTM D-5191	

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TABLE VI

JOB NUMBER:	LABORATORY TESTS RESULTS		TEST METHOD	DATE
	05/28/99	ATTN: Attn		
CLIENT I.D.....: CARBOB 90/10 REVERSE	BASE + 10% ETOH	LABORATORY I.D.....: 990554-0042		
DATE SAMPLED.....: 05/20/99	+ 1% AAE + 75% NEODOL	DATE RECEIVED.....: 05/20/99		
TIME SAMPLED.....: 16:01	+ 12.5% ODE	TIME RECEIVED.....: 16:01		
WORK DESCRIPTION....: CARBOB 90/10 REVERSE	+ 12.5% ATLAS	REMARKS.....: 1-500ml amber btl		
TEST DESCRIPTION	FINAL RESULT	LIMIT/DILUTION	UNITS OF MEASURE	
REID EQUIVALENT VAPOUR PRESSURE	*1		PSI	ASTM D-5191
RVP CARB CALCULATION	6.56	0.10	PSI	ASTM D-5191 (CARB)
RVP EPA CALCULATION	6.80	0.10	PSI	ASTM D-5191 (EPA)
RVP ASTM CALCULATION	6.67	0.10	PSI	ASTM D-5191 (ASTM)
PRESSURE TOTAL/GRABNER INSTRUMENT	7.48	0.10	PSI	ASTM D-5191

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TABLE VII

LABORATORY TESTS RESULTS 05/28/99		ATTN: Attn	
CLIENT I.D.....: CARBOB 90/10 (RECHECK)		LABORATORY I.D.....: 990554-0043	
DATE SAMPLED.....: 05/27/99		DATE RECEIVED.....: 05/27/99	
TIME SAMPLED.....: 16:01		TIME RECEIVED.....: 16:01	
WORK DESCRIPTION....: CARBOB 90/10 (RECHECK)		REMARKS.....: 1-500ml amber btl	
TEST DESCRIPTION	FINAL RESULT	LIMIT/DILUTION	UNITS OF MEASURE
REID EQUIVALENT VAPOUR PRESSURE	*1	0.10	PSI
RVP CARB CALCULATION	7.22	0.10	PSI
RVP EPA CALCULATION	7.47	0.10	PSI
RVP ASTM CALCULATION	7.34	0.10	PSI
PRESSURE TOTAL/GRABNER INSTRUMENT	8.18	0.10	PSI
			TEST METHOD
			ASTM D-5191
			05/28/99
			ASTM D-5191 (CARB)
			ASTM D-5191 (EPA)
			ASTM D-5191 (ASTM)
			ASTM D-5191

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TABLE VIII

LABORATORY TESTS RESULTS		05/28/99		ATTN: Attn	
CLIENT I.D. ....:	CARBOB 90/10 LN (RECHECK)	LABORATORY I.D. ....:	990554-0044		
DATE SAMPLED....:	05/27/99	DATE RECEIVED.....:	05/27/99		
TIME SAMPLED....:	16:01	TIME RECEIVED....:	16:01		
WORK DESCRIPTION...:	CARBOB 90/10 LN (RECHECK)	REMARKS.....:	1-500ml amber btl		
TEST DESCRIPTION	FINAL RESULT	UNITS/DILUTION	UNITS OF MEASURE	TEST METHOD	DATE
REID EQUIVALENT VAPOUR PRESSURE	*1		PSI	ASTM D-5191	05/28/99
RVP CARB CALCULATION	6.76	0.10	PSI	ASTM D-5191 (CARB)	
RVP EPA CALCULATION	7.01	0.10	PSI	ASTM D-5191 (EPA)	
RVP ASTM CALCULATION	6.88	0.10	PSI	ASTM D-5191 (ASTM)	
PRESSURE TOTAL/GRABNER INSTRUMENT	7.70	0.10	PSI	ASTM D-5191	

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TABLE IX

LABORATORY TESTS RESULTS 05/28/99			
CLIENT I.D. DATE SAMPLED TIME SAMPLED WORK DESCRIPTION		LABORATORY I.D. DATE RECEIVED TIME RECEIVED REMARKS	
CARBOB 90/10 REVERSE (RECHECK)			990554-0046
JOB NUMBER: 990554	05/27/99	ATTN: Attn	05/27/99
DATE SAMPLED.....	05/27/99	TIME RECEIVED.....	05/27/99
TIME SAMPLED.....	16:01	TIME RECEIVED.....	16:01
WORK DESCRIPTION....	CARBOB 90/10 REVERSE (RECHECK)	REMARKS.....	1-500ml amber btl
TEST DESCRIPTION	FINAL RESULT	LIMITS/DILUTION	UNITS OF MEASURE
REID EQUIVALENT VAPOUR PRESSURE	*1	0.10	PSI
RVP CARB CALCULATION	6.56	0.10	PSI
RVP EPA CALCULATION	6.30	0.10	PSI
RVP ASTM CALCULATION	6.67	0.10	PSI
PRESSURE TOTAL/GRABNER INSTRUMENT	7.48	0.10	PSI
			ASTM D-5191
			ASTM D-5191 (CARB)
			ASTM D-5191 (EPA)
			ASTM D-5191 (ASTM)
			ASTM D-5191
			05/28/99
			TEST METHOD
			DATE

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TABLE X

## Fuel Summary CARB Gasoline vs CARB Gasoline + AAE10 @ 1000ppm

Test No.	Vehicle	Fuel Tested EPA-75	THC g/mile	CO g/mile	NOx g/mile	CO2 g/mile	CH4 g/mile	NMHC g/mile	MPG
5736	1993 Ford Explorer	CARB Base, Seq#1	0.151	1.697	0.239	524.16	0.027	0.1196	16.183
5736	1996 GMC Jimmy	CARB Base, Seq#1	0.218	2.744	0.288	485.79	0.03	0.1835	17.387
5675	1998 Dodge Ram	CARB Base, Seq#1	0.135	1.427	0.132	582.37	0.021	0.1103	14.586
5682	1991 Geo Prizm	CARB Base, Seq#1	0.348	3.269	0.372	289.68	0.031	0.3129	28.84
5736	1996 Nissan Sentra	CARB Base, Seq#1	0.073	0.772	0.148	289.58	0.008	0.0638	29.323
5734	1994 Nissan Sentra	CARB Base, Seq#1	0.17	1.878	0.368	308.26	0.017	0.1511	27.373
	Average		0.183	1.964	0.258	413.305	0.022	0.157	22.282
Test No.	Vehicle	Fuel Tested EPA-75	THC g/mile	CO g/mile	NOx g/mile	CO2 g/mile	CH4 g/mile	NMHC g/mile	MPG
5691	1993 Ford Explorer	CARB + AAE10, Seq#2	0.18	1.586	0.245	532.46	0.029	0.1479	15.935
5684	1996 GMC Jimmy	CARB + AAE10, Seq#2	0.202	2.524	0.287	493.70	0.028	0.1695	17.125
5686	1998 Dodge Ram	CARB + AAE10, Seq#2	0.194	1.712	0.115	592.59	0.024	0.1662	14.32
5700	1991 Geo Prizm	CARB + AAE10, Seq#2	0.326	3.416	0.41	287.52	0.036	0.2846	29.035
5745	1996 Nissan Sentra	CARB + AAE10, Seq#2	0.074	0.785	0.129	294.62	0.008	0.0659	28.82
5747	1994 Nissan Sentra	CARB + AAE10, Seq#2	0.182	1.869	0.392	308.29	0.018	0.1613	27.369
	Average		0.193	1.982	0.263	418.199	0.024	0.166	22.101
	Deviation +/-		5.66%	0.89%	1.92%	1.18%	7.51%	5.70%	-0.81%

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TABLE XI  
Fuel Summary EPA vs EPA + AAE10 @ 1000ppm

Test No.	Vehicle	Fuel	THC g/mile	CO g/mile	NOx g/mile	CH4 g/mile	NMHC g/mile	MPG
5708	1993 Ford Explorer	EPA Base, Seq#3	0.223	2.316	0.34	539.82	0.043	15.682
5893	1996 GMC Jimmy	EPA Base, Seq#3	0.242	2.882	0.453	499.87	0.042	16.893
5692	1998 Dodge Ram	EPA Base, Seq#3	0.249	2.466	0.19	600.43	0.046	14.103
5708	1991 Geo Prizm	EPA Base, Seq#3	0.327	3.392	0.446	294.90	0.035	28.328
5752	1996 Nissan Sentra	EPA Base, Seq#3	0.165	1.038	0.208	299.19	0.012	28.318
5753	1994 Nissan Sentra	EPA Base, Seq#3	0.253	2.952	0.333	315.84	0.023	26.562
	Average		0.243	2.508	0.328	425.009	0.034	21.648
Test No.	Vehicle	Fuel	THC g/mile	CO g/mile	NOx g/mile	CH4 g/mile	NMHC g/mile	MPG
5709	1993 Ford Explorer	EPA + AAE10, Seq#4	0.234	2.744	0.351	534.78	0.048	15.808
5701	1996 GMC Jimmy	EPA + AAE10, Seq#4	0.324	3.141	0.517	500.54	0.046	16.848
5702	1998 Dodge Ram	EPA + AAE10, Seq#4	0.315	3.308	0.227	598.06	0.056	14.123
5717	1991 Geo Prizm	EPA + AAE10, Seq#4	0.365	3.952	0.519	294.89	0.034	28.235
5758	1996 Nissan Sentra	EPA + AAE10, Seq#4	0.185	1.299	0.187	300.57	0.014	28.146
5759	1994 Nissan Sentra	EPA + AAE10, Seq#4	0.30	3.308	0.371	313.13	0.025	26.729
	Average		0.287	2.959	0.362	423.663	0.037	21.648
	Deviation +/-		18.00%	17.99%	10.27%	-0.32%	10.16%	19.45%
								0.00%

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TABLE XII

## Fuel Summary Gasohol vs Gasohol + AAE00 @ 4600 ppm

Test No.	Vehicle	Fuel Tested EPA-75	THC g/mile	CO g/mile	NOx g/mile	CO2 g/mile	CH4 g/mile	NMHC g/mile	MPG
5722	1993 Ford Explorer	Gasohol Base, Seq#5	0.165	1.545	0.251	519.43	0.033	0.1275	16.336
5711	1996 GMC Jimmy	Gasohol Base, Seq#5	0.219	2.359	0.342	495.15	0.037	0.1765	17.083
5710	1998 Dodge Ram	Gasohol Base, Seq#5	0.219	2.102	0.194	589.97	0.047	0.1655	14.367
5727	1991 Geo Prizm	Gasohol Base, Seq#5	0.273	3.804	0.452	283.54	0.037	0.2309	29.549
5764	1996 Nissan Sentra	Gasohol Base, Seq#5	0.118	0.907	0.175	295.48	0.012	0.1046	28.706
5766	1994 Nissan Sentra	Gasohol Base, Seq#5	0.194	2.237	0.388	311.28	0.022	0.1694	27.056
	Average		0.198	1.992	0.30	415.807	0.032	0.162	22.183
Test No.	Vehicle	Fuel Tested EPA-75	THC g/mile	CO g/mile	NOx g/mile	CO2 g/mile	CH4 g/mile	NMHC g/mile	MPG
5726	1993 Ford Explorer	Gasohol + AAE00, Seq#6	0.17	1.48	0.26	515.20	0.035	0.1312	16.472
5770	1996 GMC Jimmy	Gasohol + AAE00, Seq#6	0.231	1.972	0.30	488.00	0.033	0.1938	17.351
5718	1998 Dodge Ram	Gasohol + AAE00, Seq#6	0.223	2.04	0.156	590.74	0.044	0.1733	14.351
5735	1991 Geo Prizm	Gasohol + AAE00, Seq#6	0.283	2.478	0.443	280.95	0.035	0.2436	29.866
5770	1996 Nissan Sentra	Gasohol + AAE00, Seq#6	0.096	0.793	0.135	294.61	0.01	0.0848	28.814
5769	1994 Nissan Sentra	Gasohol + AAE00, Seq#6	0.17	1.846	0.381	314.49	0.019	0.1492	26.842
	Average		0.196	1.768	0.279	413.998	0.029	0.163	22.282
	Deviation +/-		-1.25%	-11.25%	-7.24%	-0.44%	-7.22%	0.16%	0.45%

# INTERNATIONAL SEARCH REPORT

Int'l. Application No  
PCT/GB 99/04155

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 C10L1/02 C10L1/14

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 C10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 17745 A (WILLIAMSON IAN VERNON ;HAZEL CLIFFORD JAMES (GB)) 30 April 1998 (1998-04-30) cited in the application page 2, paragraph 2; claims 1,52; examples 2,6,10 page 4 ---	1,5-15, 18-21,23
A	EP 0 466 511 A (ETHYL PETROLEUM ADDITIVES INC) 15 January 1992 (1992-01-15) page 5 --- -/-	21

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents :

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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2000	04/05/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer  De La Morinerie, B

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 99/04155

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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